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METHOD FOR TRANSMITTING INFORMATION BY MEANS OF DIGITAL TRANSMISSION SIGNALS

The invention relates to a method of transmitting information by means of digital transmission signals, in particular radio signals, wherein the transmission signals include a predeterminable transmission frequency, and wherein the transmission frequency is converted in a signal receiver.

Methods of the kind under discussion for transmitting information are known from practice, and they exist in an assortment of variations. In this connection, the digital transmission signals are represented by mostly sinusoidal signals. The transmission signals are formed by radio signals, for example, in mobile radio networks, electrical signals in landline networks, which are transmitted, for example, via copper cables, lightwave signals, electrooptical signals, or acoustical signals. In this connection, a transmission of the lightwave signals is possible in optical waveguides, for example, fiber glass. Transmission occurs via one or more predeterminable transmission frequencies.

With one exception, a conversion of the transmission signal frequency always occurs in a signal receiver for purposes of detecting a transmission signal. This exception are the earliest known "Hertz radio receivers", which were designed and constructed as spark gaps, and which detected the radio signal power directly, without any frequency conversion step, in the form of spark gap flashovers. The simplest, known types of signal receivers, which detected the transmission signals by means of frequency conversions, are the so-called crystal sets, which use for the frequency conversion step the so-

called crystal, an early form of a semiconductor diode. In all so-far known signal receivers, which operate by means of frequency conversion steps or frequency mixing, the frequency conversion is performed exclusively by means of nonlinear frequency conversion steps, i.e., with the use of a mathematical nonlinear transformation equation for the transmission signal frequency. The technical realization of the mathematical nonlinear transformation of the transmission signal or its frequency position utilizes the nonlinear characteristic curve of active or passive, electronic or electrooptical components. "Each frequency mixing makes use of the nonlinear characteristic curve of active or passive components," as can be read in the technical literature, for example, Lehrbuch der Nachrichtenübertragungstechnik -- Grundlagen -- Komponenten -- Verfahren -- Systeme, Ulrich Freyer, Hanseverlag 1988, ISBN 3-446-15137, p. 126, Chapter 1.3.6.1. See also, "Lehrbuch der Hochfrequenztechnik," Vol. 2, Zinke Brunswig, Springer Verlag 1987, ISBN 0-540-17042-1, the entire chapter 11. The frequency mixing may occur additively, i.e., while supplying the signals to be mixed to the same input of the mixing circuit, or multiplicatively, i.e., while supplying the signals to be mixed to different inputs of the mixing circuit. However, both methods are understood to be nonetheless nonlinear methods in the meaning of the foregoing description.

Having in mind to describe the present invention as simply as possible, the following will consider as transmission signals, for example, radio signals. Within the scope of the known radio transmission technique, one uses for selecting transmission signals resonance filters, which exhibit a finite resonator quality with such a wide frequency

response that transmission signals being separated are bound to keep a certain minimal frequency distance from one another, so as to still enable a separation. Until now, it has been impossible to separate transmission signals with strongly superposed frequency spectra or power density spectra.

The known methods of transmitting information are problematic in that the known resonance filters require a frequency bandwidth of the transmission system, which is far larger than the minimal frequency bandwidth known from the communication theory. The consequence thereof is that the suitable and available frequency ranges are used extremely ineffectively, and that only barely usable frequencies are available for new transmission systems.

It is therefore the object of the present invention to describe a method of transmitting information by means of digital transmission signals, wherein the available and suitable transmission frequencies are effectively used in a simple manner.

The foregoing object is accomplished by a method comprising the steps of claim 1. Accordingly, a method of transmitting information by means of digital transmission signals is characterized in that a conversion occurs by superposing a transmission signal with at least one additional signal of a predeterminable frequency on a component with a linear characteristic curve, and that the frequency of the additional signal is selected such that the superposition generates a beat pattern.

In accordance with the invention, it has been recognized that the foregoing object is accomplished in a surprisingly simple manner by converting the transmission frequency by means of superposing another frequency on a

component with a linear or without a nonlinear characteristic curve. The conversion uses no nonlinear characteristic curves of the component. To this end, the frequency of the additional signal being superposed is to be selected such that the superposition generates a beat. The superposed signal will then contain a differential frequency portion of the superposed frequencies. The beat pattern, which is generated by the linear superposition of sinusoidal frequency signals -- the transmission signal and the additional signal -- is characteristic of the contained transmission signal. The beat pattern is dependent only on the mid-frequencies of the interfering individual signals. The generation of beat patterns makes it possible to separate transmission signals, whose power density spectra overlap. Consequently, it is possible to develop a transmission system, whose transmission frequencies are considerably closer to one another than has been possible with previous transmission systems. Thus as a whole, transmission systems are obtained, which require a considerably smaller frequency bandwidth.

Consequently, the method of the present invention discloses a method, wherein the available and suitable transmission frequencies are effectively used in a simple manner.

In the method of the present invention, the beat is used to separate sinusoidal frequency signals with small mid-frequency distances despite superposed power density spectra. Such a beat filtering method uses the characteristic that after the interference, frequency signals with certain mid-frequencies generate characteristic signal time patterns in the form of beat patterns. From the characterization of these beat

patterns, one may again infer frequency signals that are contained therein.

In the presence of a mixture of frequency signals, an additional signal of a certain frequency generates, together with a corresponding frequency signal, a clear change in the total signal.

To ensure that the total signal changes as clearly as possible, the frequency of the additional signal could be close to the transmission frequency of the transmission signal. The closer the frequency of the additional signal to the transmission frequency, the more distinct is the change in the total signal. The duration or pulse length of the signals, which correlates with the Fourier power density spectrum, has no influence on the development of the beat pattern as a function of the change in the frequency difference between the transmission signal and additional signal.

With a view to separating transmission signals of different frequencies as satisfactorily as possible, it would be possible to prefilter the transmission signals before they are superposed. Since the separation of signals with different frequencies is dependent on the existing interference power by other signals, it is the object of a prefiltration, among other things, to suppress in the superposed signal the number of simultaneous interference signals with different frequencies as much as possible, thereby improving in the beat pattern clearly the difference between the conditions with and without a transmitted signal.

Depending on the requirement, it would be possible to amplify the transmission signals before the superposition, thereby enabling the generation of more characteristic differences in the beat patterns with and without a transmission signal.

To generate especially representative beat patterns, it would be possible to adapt the level of the additional signal to the transmission signal, or vice versa. As a result, the signals could have an almost identical amplitude.

With a view to using larger dynamic ranges of the receiving range levels of transmission signals, it would be possible to amplify the alternating current of the beat patterns. An amplification of the alternating current has shown to be more effective and more favorable than a direct current amplification.

In a simple manner, it would be possible to detect the transmission signals by counting the signal extremes -- signal maxima and/or signal minima -- which resulted in the beat pattern. To this end, it would be preferred to use threshold switches.

As an alternative or in addition thereto, it would be possible to detect the transmission signals by comparing the integrated signal power from predeterminable time windows of the beat pattern. To this end, it would be possible to select at least two time windows. When a transmission signal is present at the signal receiver, a beat pattern generated by superposing the additional signal will show a different characteristic response than in the absence of a transmission signal. Such a frequency-selective, characteristic difference follows from the phenomenon that certain frequencies in a superposed signal time pattern generate different dominating effects in certain time ranges.

An examination of the beat based on a computer simulation showed that in the presence of the transmission signal to be detected, the integrated pulse power of the superposed signal significantly decreases in

the signal edges and significantly increases in the midrange of the signal, in the event of a suitable selection of the differential frequency between the additional signal and the transmission signal or interference signals, their phase position relative each other, the pulse duration, and the chronological superposition of the signals. The examination further showed that the slightest existing frequency difference generates the strongest usable effect or the greatest influence on the superposed signal time pattern or beat pattern. For this reason, it would be possible to select the frequency of the additional signal that is to be examined, closest to the transmission frequency that is to be detected.

It will be possible to obtain a particularly precise detection, when the time windows are selected both in the chronological midrange and edge range of the beat pattern. Even more favorable would be a selection of the time windows in the midrange and in the two edge ranges of the beat pattern. For an evaluation, it would be possible to integrate the two power signals in the two edge ranges and in the then remaining midrange, and to compare them by forming a ratio. The comparison occurs between a situation with an existing transmission signal and a situation without a transmission signal.

To realize a particularly reliable transmission method, it would be possible to allocate at least one transmission signal to each transmission frequency. In so doing, it would be possible to select the frequency of the additional signal for ensuring a clear detection between the transmission frequency and a directly adjacent, further transmission frequency. To further ensure a clear detection, it would be possible to select the frequency of the additional signal outside the center

between two adjacent transmission frequencies. At any rate, the selection of the frequency of the additional signal must take into account that the beat detection of the present invention is capable of detecting only frequency differences. Consequently, an asymmetric selection of the frequency of the additional signal between equidistant radio channels is favorable. In the case that an additional signal frequency lies exactly in the center between two adjacent transmission frequencies, the detection of the transmission signals will no longer be clear in the two channels allocated to the transmission frequencies. Both adjacent signals will then generate the same beat effect. The distance ratio of the frequency of the additional signal between two transmission frequencies may be, for example, 1 to 2.

To simplify the layout of a signal receiver, one could select a directly adjacent transmission frequency. In so doing, one could do without providing additional oscillators for the additional signal besides the transmission oscillators already required for the transmission frequencies. To ensure the unambiguousness of the signal detection, it would then be advantageous to arrange the transmission frequencies at unequal distances.

In a further, advantageous variation of the method, it would be possible to select as frequencies of the additional signal, two equidistant transmission frequencies that are symmetric with the transmission signal, in particular two directly adjacent, equidistant transmission frequencies. In the case of such a selection, equidistance is necessary. The use of such frequencies generates in the selected parameter range a beat pattern, which can be better evaluated as regards

the integration in the different time windows than the use of only a single additional signal frequency.

Since a beat pattern depends on the differential frequency between the additional and the transmission signal, their phase position relative to each other, the pulse duration, and the chronological superposition of the signals, it will be advantageous with respect to the precision of the detection, when a signal transmitter and the signal receiver are synchronized. This permits ensuring the required phase position and the complete time overlap of the signals. To this end, one could associate a radio clock to the signal transmitters and signal receivers. This radio clock could be used to control the transmission and receiving windows. In this connection, it will further be advantageous, when the signal transmitters and signal receivers transmit and receive according to a predeterminable timing sequence. With that, the point in time of the generation of a beat pattern is predetermined, namely each time at the beginning of a cycle. In a very practical manner, one could control the timing sequence via a radio clock.

The quality of the detection depends substantially on the power of the existing interference signals. To attenuate the interference signal power, it would be possible to transmit and receive the transmission frequency with a right-hand and left-hand circular polarization alternating with each other. This polarity reversal could occur at any transmission frequency.

An electrooptical component could be used as the converting component.

There exist various possibilities of improving and further developing the teaching of the present

invention in an advantageous manner. To this end, reference may be made on the one hand to the dependent claims and on the other hand to the following description of test results of the method according to the invention with reference to the drawing, in which:

Figure 1 is a typical measuring diagram of a beat pattern about the midrange of a transmission frequency in the absence of a transmission signal;

Figure 2 is a typical measuring diagram of a beat pattern about the midrange of the transmission frequency of Figure 1 in the presence of a transmission signal; and

Figure 3 is a measuring diagram for documenting the ratio of the integrated powers with and without transmission signal.

To illustrate the method according to the invention for transmitting information, the following will discuss test results for a certain selection of beat parameters. These results were obtained by computing the superposition of up to ten sinusoidal signals in a common signal pulse interval. To this end, representative Fourier integrals of band-limited square signals and representative Fourier series of periodic, band-limited square signals were used within the scope of a numeric computation. The computation was performed with the "Maple-V-Release4" computation program.

It showed that for examining the problems, it fully suffices to use the simplest representation by monochromatic sine functions, which were observed only in the pulse interval. For an evaluation, the power signals of the superposed signal were integrated in three different pulse ranges -- the two edge ranges and the midrange -- and compared by forming a ratio. This was

performed with a transmission signal present and without a transmission signal.

Figure 1 is a typical measuring diagram illustrating the envelope of a beat pattern about the midrange of a transmission frequency in the absence of a transmission signal. Figure 2 is a typical measuring diagram illustrating the beat pattern of Figure 1 in the presence of a transmission signal. This can be noted from the clear signal change in the edge range of the signal. The measuring diagrams of Figures 1 and 2 are amplitude time diagrams.

Figure 3 illustrates in a measuring diagram the ratio of the integrated powers with and without a transmission signal. In the diagram, the ratio of integrated power in the midrange to integrated power in the two edge ranges is plotted in each measuring point. The ratio of interference power to signal power is plotted along the x-axis.

During the detection, a received transmission signal is superposed subsequent to the input filters, while adapting the level to the additional signal. Subsequently the superposed signal is detected and squared, and integrated in the time windows.

The results in the diagram of Figure 3 relate to a superposition of signals with the same individual signal amplitude, wherein the interference power is successively increased from 1 to 9 nine channels. It was found that during the superposition, different signal amplitudes of the individual signals, and an increasing number of signals with different frequencies and a different frequency composition of the signals have no influence on the detection behavior of the method according to the invention. An impairment of the

detection behavior is effected substantially exclusively by an increased interference power.

Because of the dependency on the interference power, the use of prefilters is advantageous in the beat detection method. By suppressing simultaneous signals of different frequencies in the transmission signal, the discrimination of the conditions with and without transmission signal is improved.

For example, for a selected transmission frequency of 433 MHz, the experiments resulted in a frequency difference between the transmission signal and the additional signal of about 15 kHz.

The smaller the additional signal power in comparison with the interference signal power, the greater is the change of the integral power ratio of the signal-ON to the signal-OFF condition, i.e., the more sensitive becomes the beat detection. On the other hand, the integral signal power of the superposed signal decreases likewise in the edges along with the decrease of the additional signal power. It is therefore necessary to select for the adjustment of the additional signal power, a compromise between a desired, highest possible sensitivity and a satisfactory detectability of the signal power. A power ratio of the additional signal to the interference signal of 1 to 4 has shown to be advantageous. With that, it is still possible to detect power signals satisfactorily in the edge ranges. Because of the integration and ratio formation, a noise is unimportant in the signal processing. Consequently, even a power ratio of 1 to 8 appears to be still usable. With that, the sensitivity of an interference power environment or the permissible interference power would increase by the factor 2.

A satisfactory discrimination is still possible, even in the case of an integral interference signal power of 100 times the transmission signal power. In this connection, the interference signal power is the signal power after the prefilter. The interference power after the prefilter, or the permissible interference power before the prefilter, can be further reduced or increased, in that differently polarized radio signals and polarization filters are used in the form of helical antennae or crossed linear antennae.

When in each transmission channel or in the case of each transmission frequency, the transmission frequency is transmitted and received with a right-hand and a left-hand polarization alternating with each other, it will be possible to attenuate the interference signal power after the polarization filter, together with the prefilter, on a statistical average at least by the factor 5.

The permissible interference power before the prefilter may thus be estimated to 2000 times the transmission signal power. Consequently, a satisfactory detection of the transmission signals is still possible on an average in a 2000 times interference environment.

The permissible dynamic range between transmission and incoming signals amounts to more than 2×10^3. It would be possible to use the detection method in the short-haul surface transmission range. For this field of application, the foregoing dynamic range is totally adequate.

Furthermore, the effect of interference signals from nonadjacent channels or nonadjacent frequencies was examined. Interference signals of high, similar, and low frequencies, such as, for example, noise or humming, may have an interfering influence on the detection

sensitivity. However, it can be assumed that as a result of evaluating the signals in the form of integration and ratio formation, low-frequency and high-frequency interferences do not affect the beat detection, since they influence all areas of integration in the same way.

A sensitive effect may arise from interference signals of similar frequency. Interferences with frequency center distances from the mid-frequency of the transmission signal, which are greater than the frequency center distance of the additional signal from the transmission signal, have no effect according to the tests. They modify only the beat pattern in a manner similar to the superposition of signals from further adjacent channels. To this end, the beat detection method of the present invention permits adapting the additional signal power to the superposed signal power, so that the additional signal keeps the dominating beat effect.

A different situation results for interferences with frequencies, which are between the mid-frequency of the transmission signal and the mid-frequency of the additional signal. In this instance, one may expect a drastic change in the beat pattern.

Within the scope of the examination, it was further found that an arbitrarily changed interference signal phase has no influence on the beat detection. The beat detection method is very immune to such interference signals.

From a mathematical view, the examinations of the beat detection method so far have shown that it is possible to implement a digital radio system with a total bandwidth of 2 MHz with 130 frequency-distinct, equidistant radio channels, with each channel having a frequency bandwidth of 50 kHz, and a channel spacing of

15 kHz, which permit a clear detection of the transmission signals in an interference power environment from signals of adjacent channels with a dynamic response better than 2×10^3. For interference signals, such as, for example, analogous radio signals in the case of a chronologically complete superposition, the transmission method of the present invention is largely immune to interferences. This is especially important for the use in frequency bands that are used many times.